

The CDF-II Time-of-Flight System

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A collaborative effort of...

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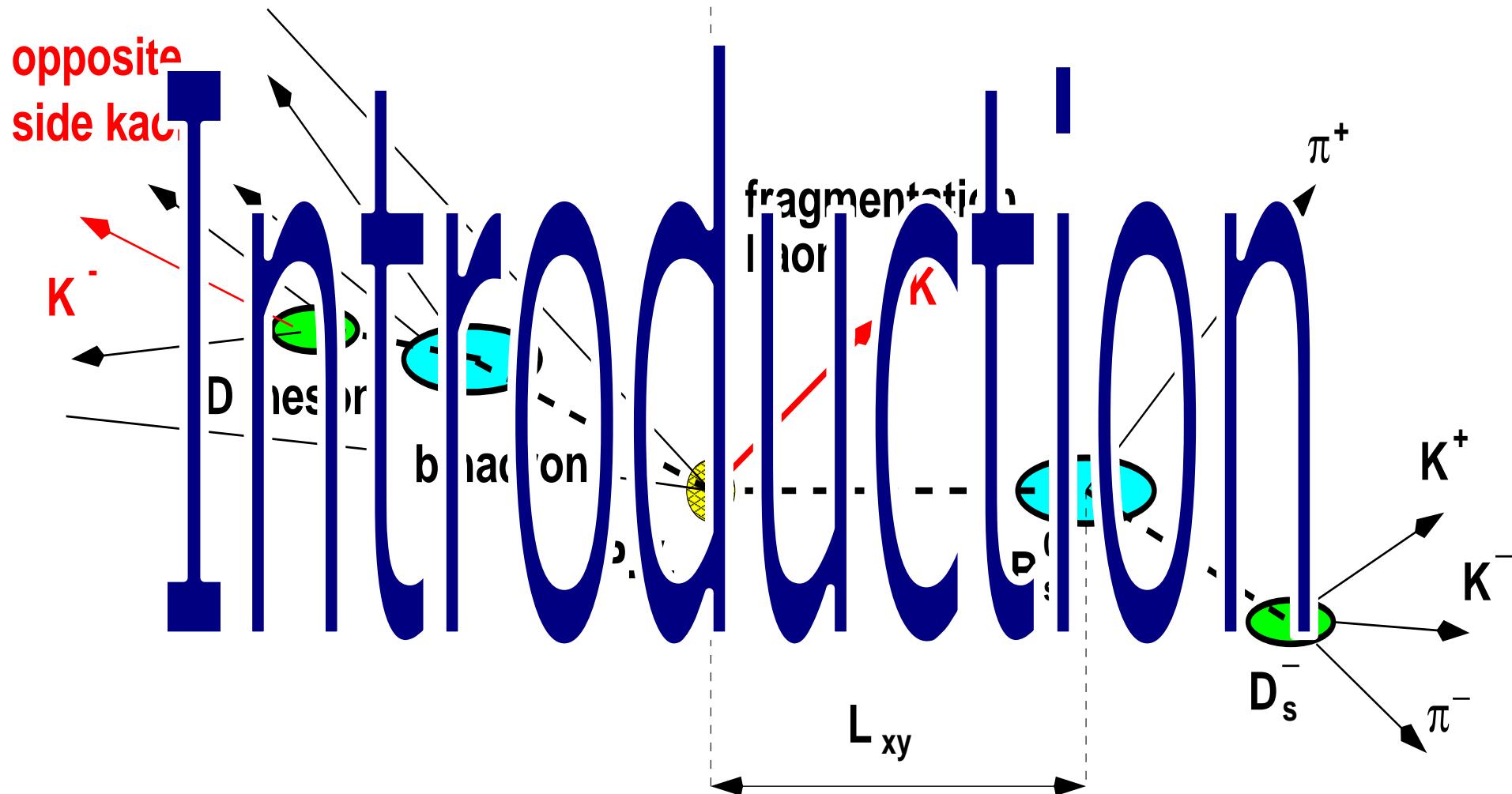
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Outline

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opposite side

same side (vertexing)



$$ct = L_{xy} \frac{m_B}{p_T}$$

Intro: Basic principles of the TOF method

- Different techniques: scintillator counters, gaseous detectors, RPCs.
- TOF detector determines speed of a charged particle by measuring flight time t across a known distance L .
- Knowing the particle momentum p , one determines the mass.

$$m = \frac{p}{c} \sqrt{\frac{c^2 t^2}{L^2} - 1}$$

- The mass resolution is mainly determined by the time resolution of the detector.

$$\sigma p / p = 1\%$$

$$\sigma L / L = 0.1\%$$

$$\sigma t / T = 2\%$$

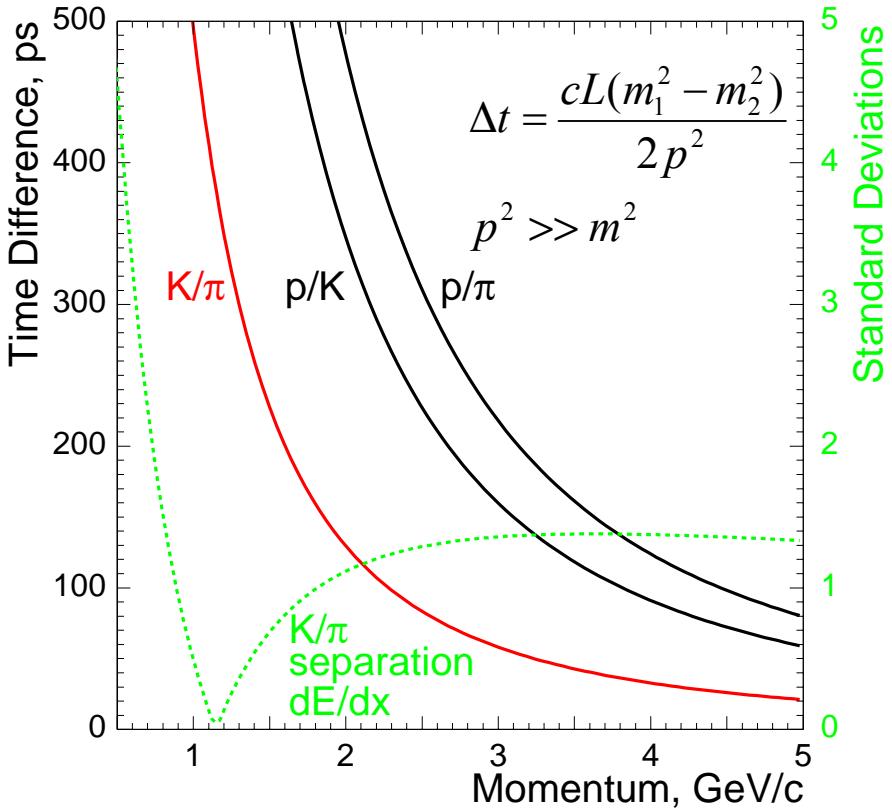
$$\gamma^2 \gg 1$$

$$\frac{\sigma m}{m} = \frac{\sigma p}{p} + \gamma^2 \left(\frac{\sigma t}{t} + \frac{\sigma L}{L} \right)$$

Intro: Particle identification @ CDF

For $L = 140$ cm $\sim R_{\text{tof}}$

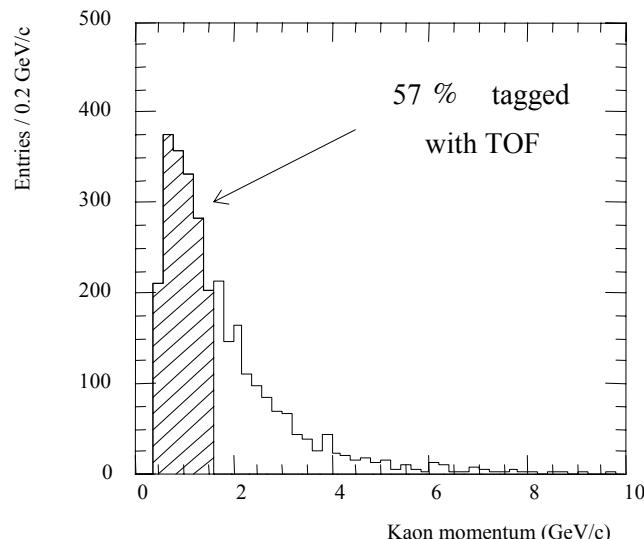
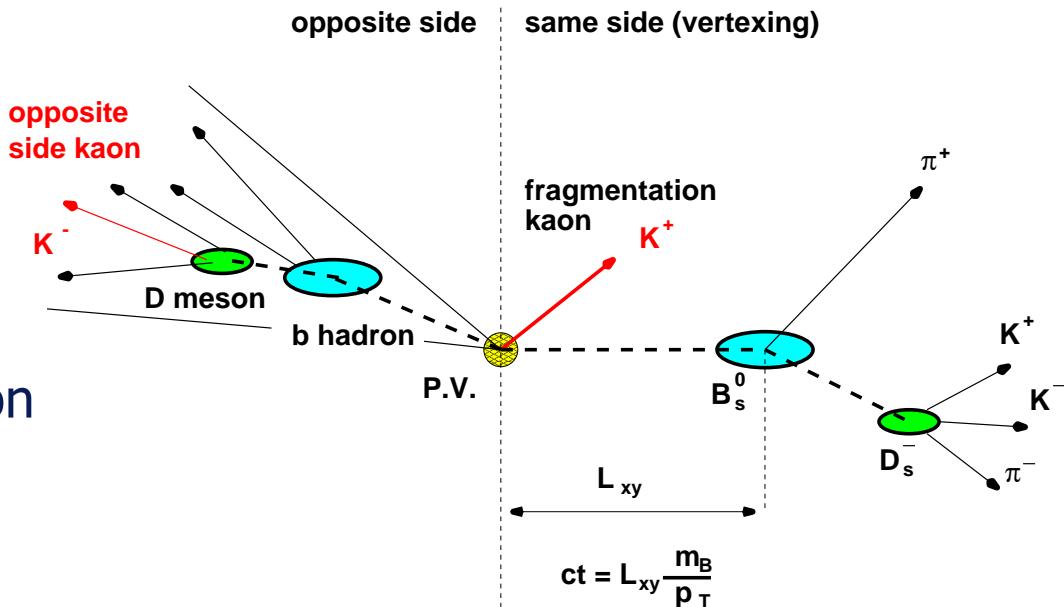
Timing resolution $\sigma_t = 100$ ps



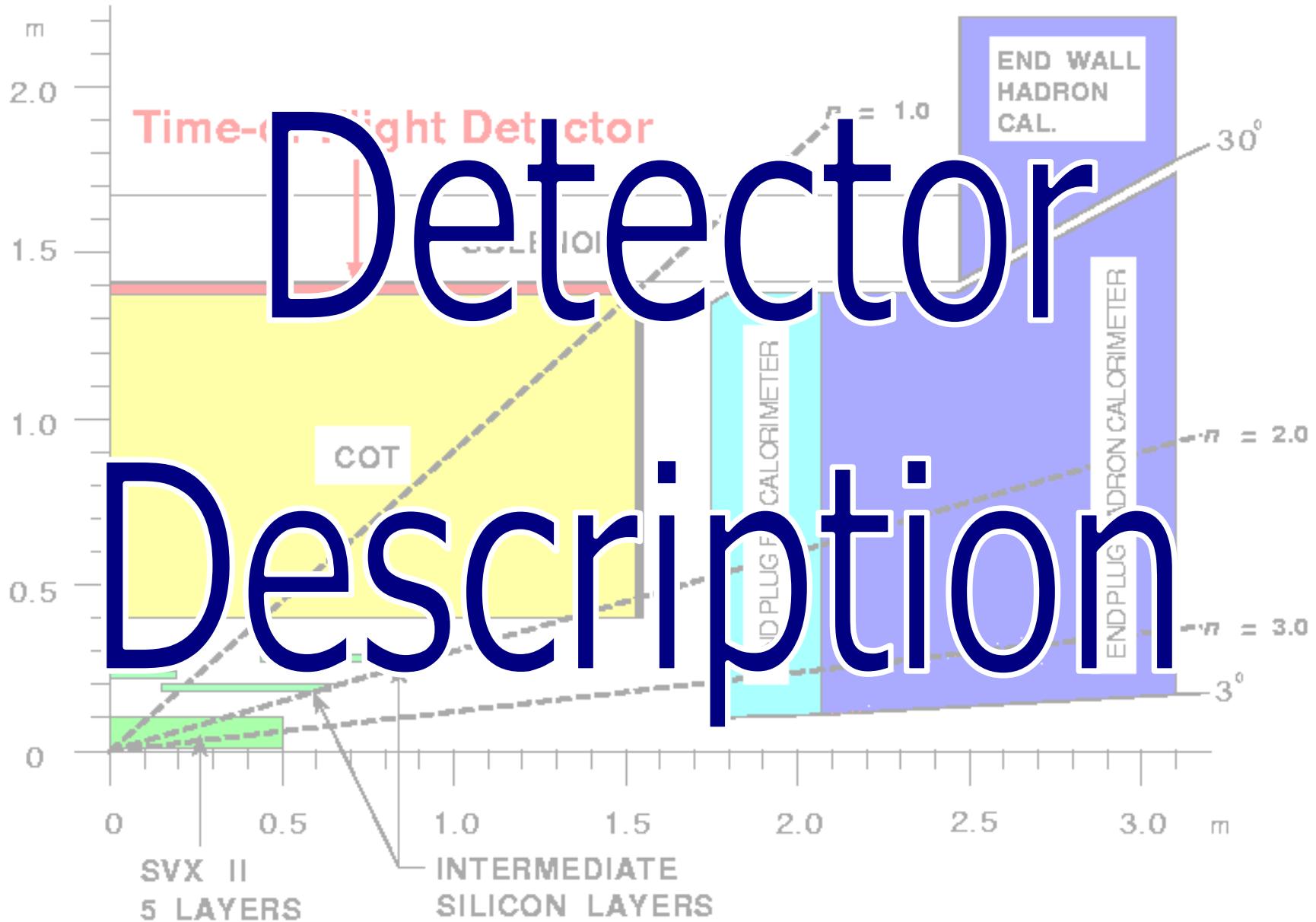
- During **CDF I** particle ID based on **dE/dx** method using the central drift chamber
- For **CDF II** a **TOF complement** **dE/dx**.
 - 2σ K/π separation $p < 1.6$ GeV/c
 - 2σ K/p separation $p < 2.7$ GeV/c
 - 2σ p/π separation $p < 3.2$ GeV/c
 - 1.2σ K/p separation over all p

Intro: Physics Motivation

- B_s physics is unique to Tevatron.
- B_s flavor oscillations and CP asymmetries require neutral **B flavor tagging** at production (b/\bar{b} content)
- New B tagger algorithm based on K identification.
- Monte Carlo simulation shows a significant fraction of the opposite side Kaon momentum Spectrum within the TOF 2σ identification range.

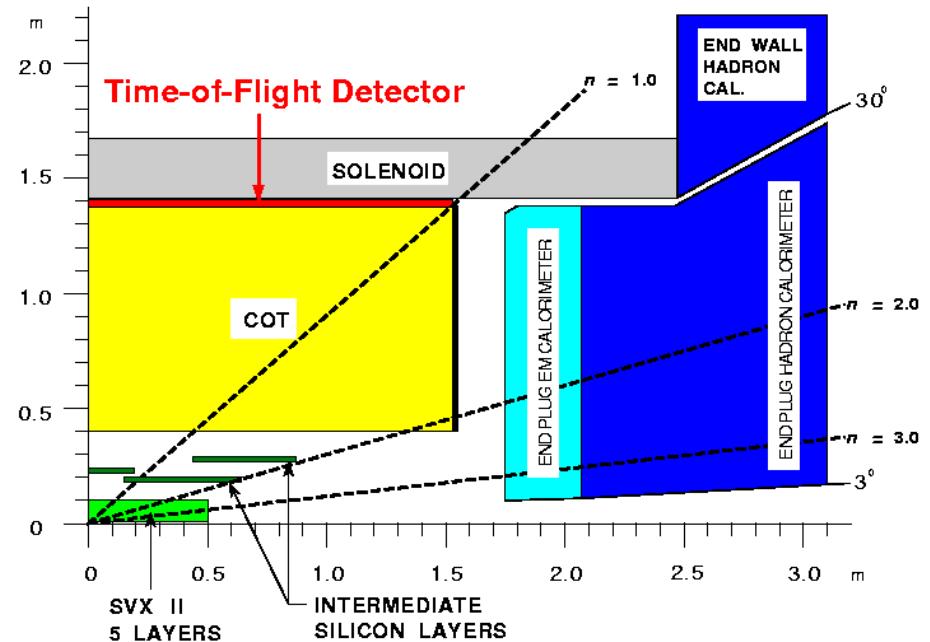


Detector Description



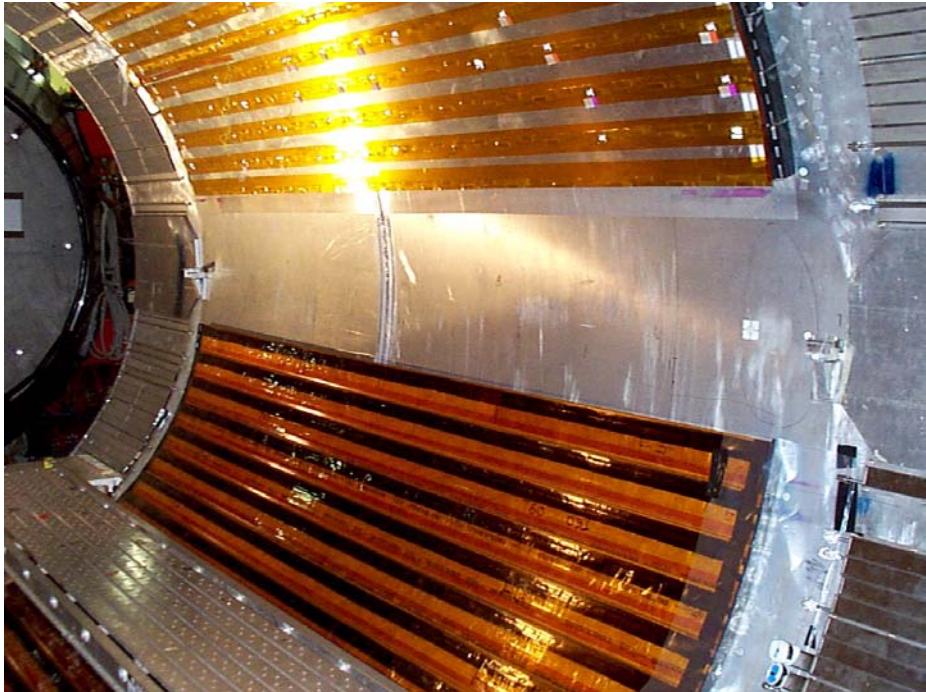
The Detector in CDF-II

- 216 Scintillator bars (279cm x 4cm x4cm) with phototubes attached to both ends (432).
- Bicron plastic scintillator BC-408 with fast rise times ~ 0.9 ns.

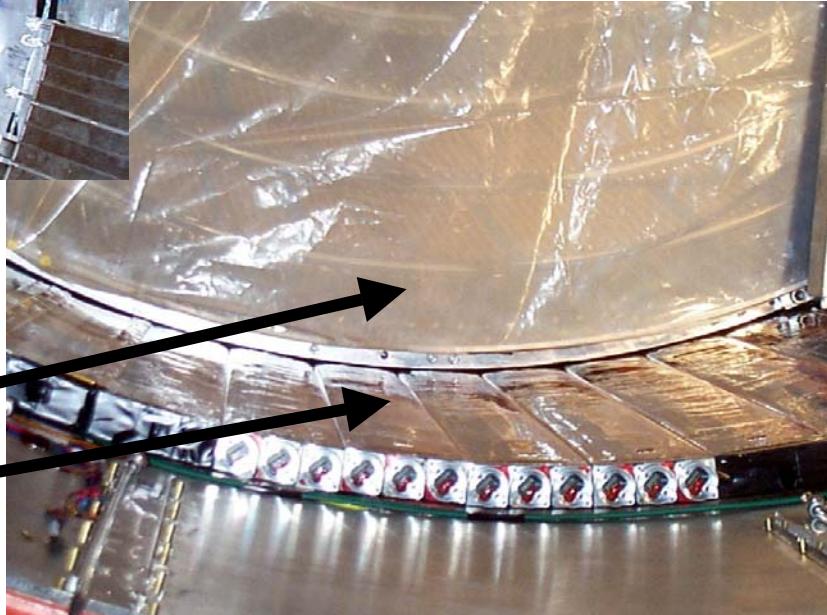


- Pseudorapidity coverage $|\eta| < 1$.
- Sandwiched between the solenoid inner wall and the central drift chamber at a radius $R \sim 1.4$ m.
- Working environment: 1.4 T B-field.

The Detector: Mechanics

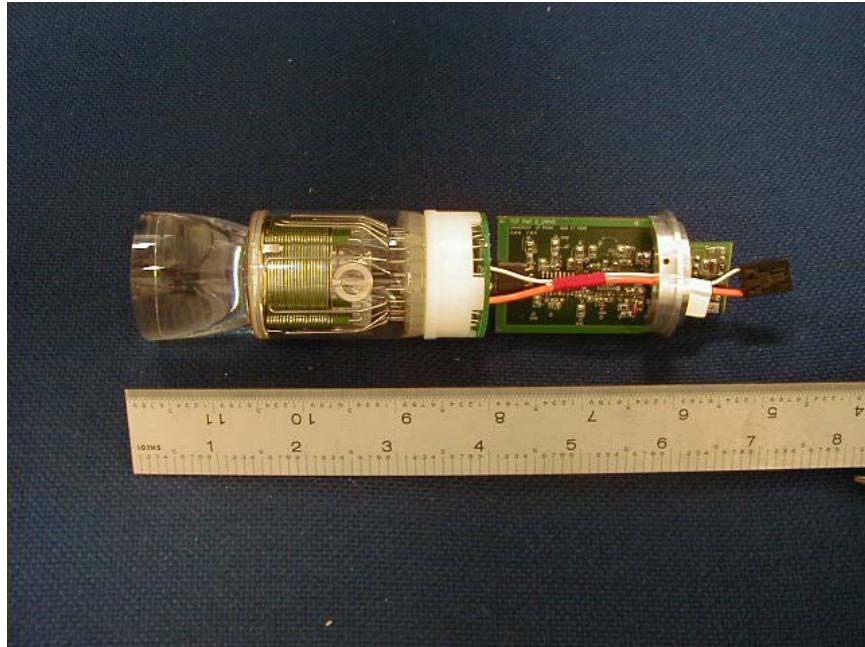


- Bars assembled in 72 triplets
- PMT held in Alu holders, not glued to allow for staged installation.



- Tight radial clearance, only a few millimeters between COT and scintillators

The Detector: Phototubes

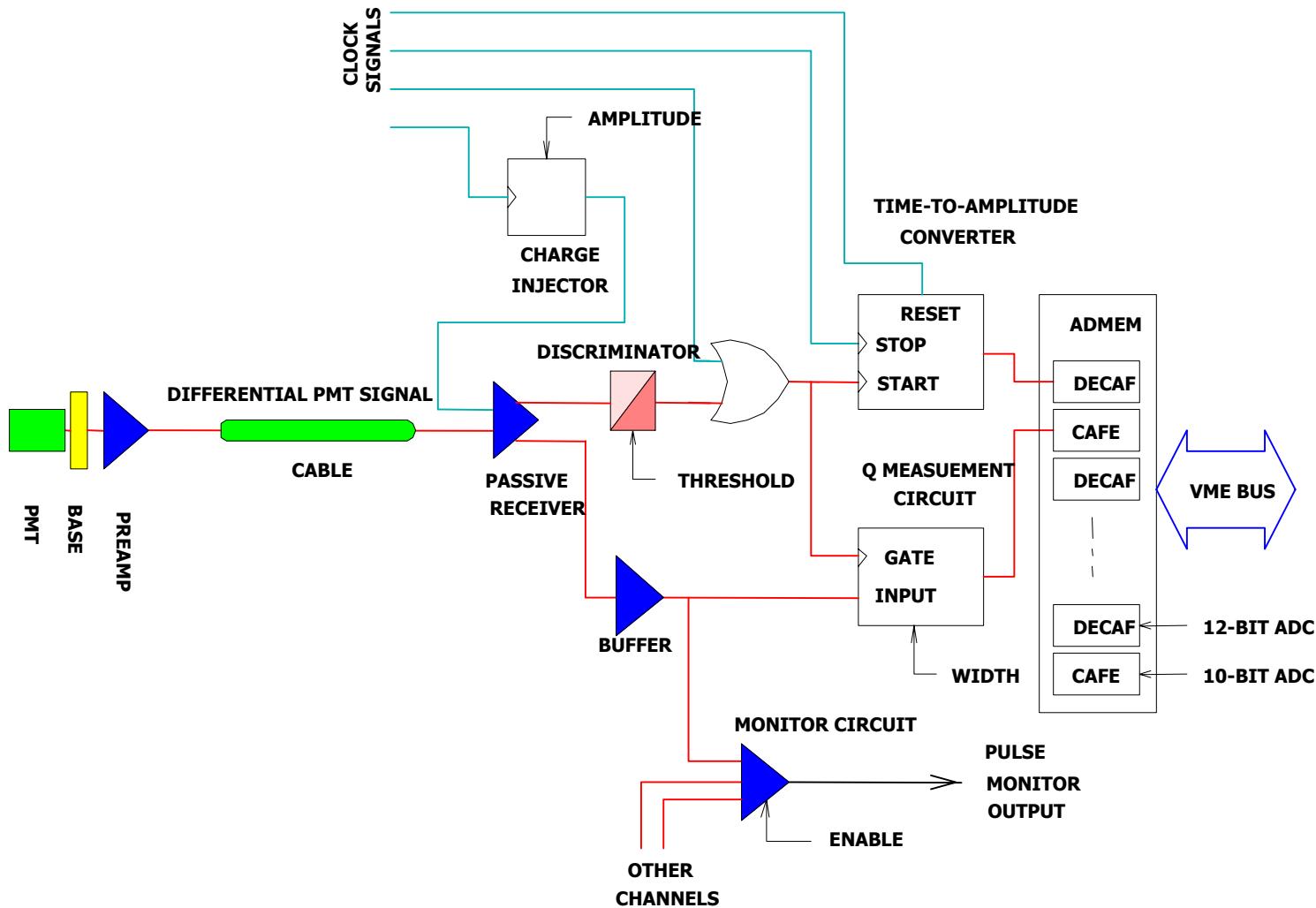


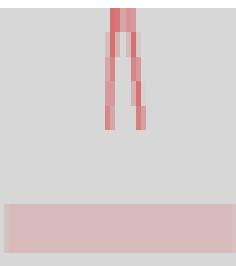
- Custom-made Hamamatsu R7766
 - 19 dynode (High gain)
 - Fine mesh (Increased tolerance to magnetic field)
 - Small size 1.5 x 2.5 inches
 - Operated with a positive HV up to 2500V
 - Gain reduction factor at $B=1.4\text{ T} \sim 500$

The Detector:Front End electronics.

- The electronics design targets < 25 ps jitter.
- CDF daq integration:
 - Clock cycle 7.58 MHz (132 ns bunch crossing).
 - Slightly modified CDF Calorimeter FE electronics (ADMEM) used + transition board.
- The differential signal from the anode and last dynode fed into preamplifier.
- The signals from the preamplifier are driven differentially to readout and split onto two paths :
 - Timing path:
 - . Leading edge discriminator (start signal TAC)
 - . Common clock (**jitter < 25ps**) (Stop signal TAC)
 - . TAC output digitized (12bits).
 - Charge path:
 - . Gated integration of charge of the pulse (10 bits)
 - . Slewing correction

The Detector: TOF Signal Path

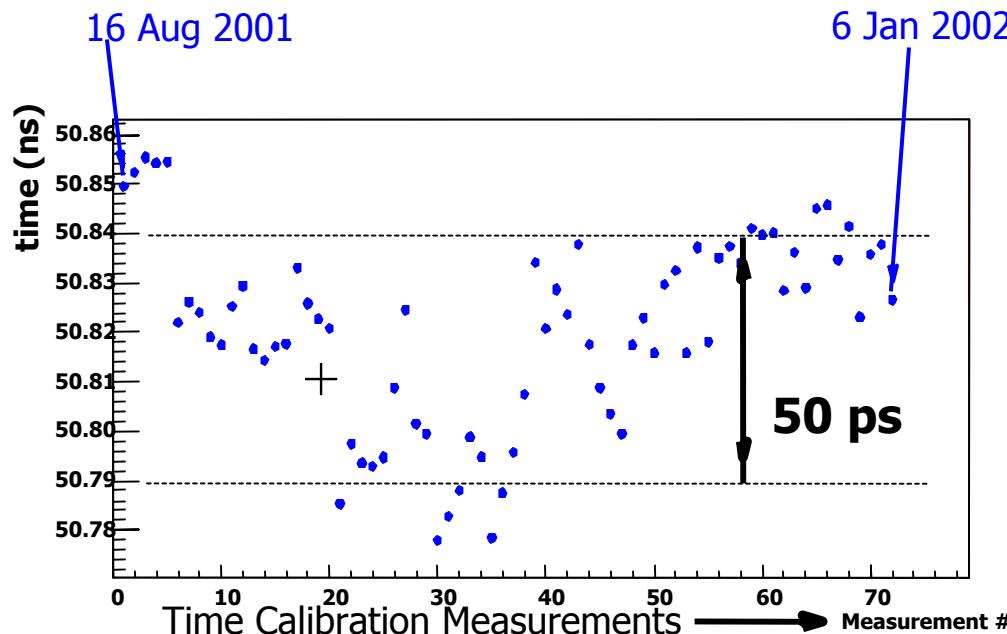




Calibration and Performance

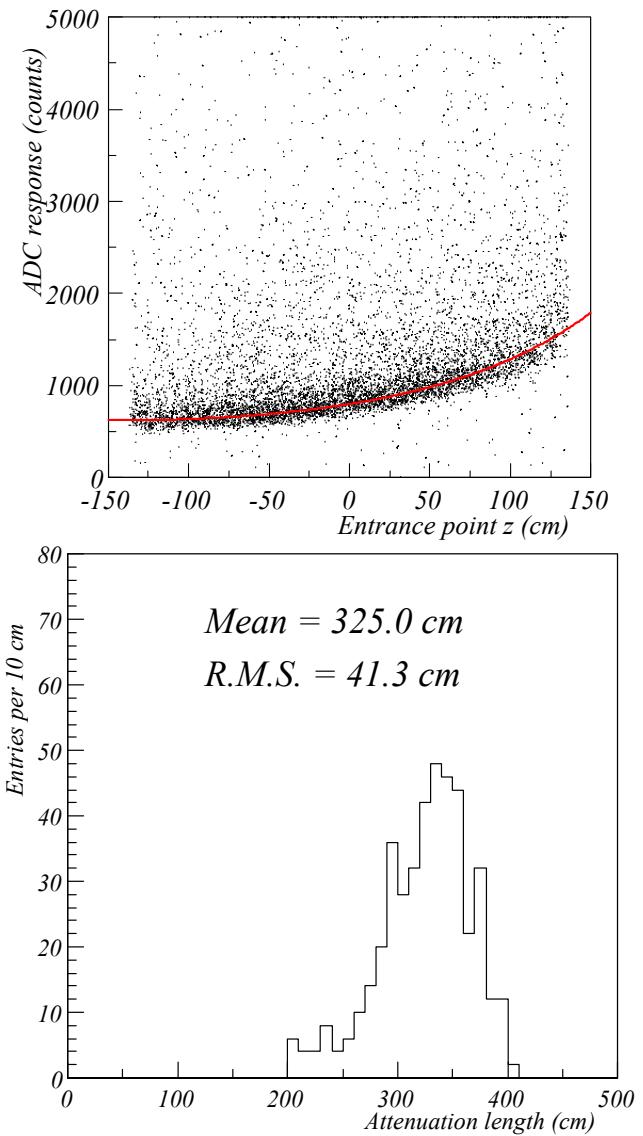
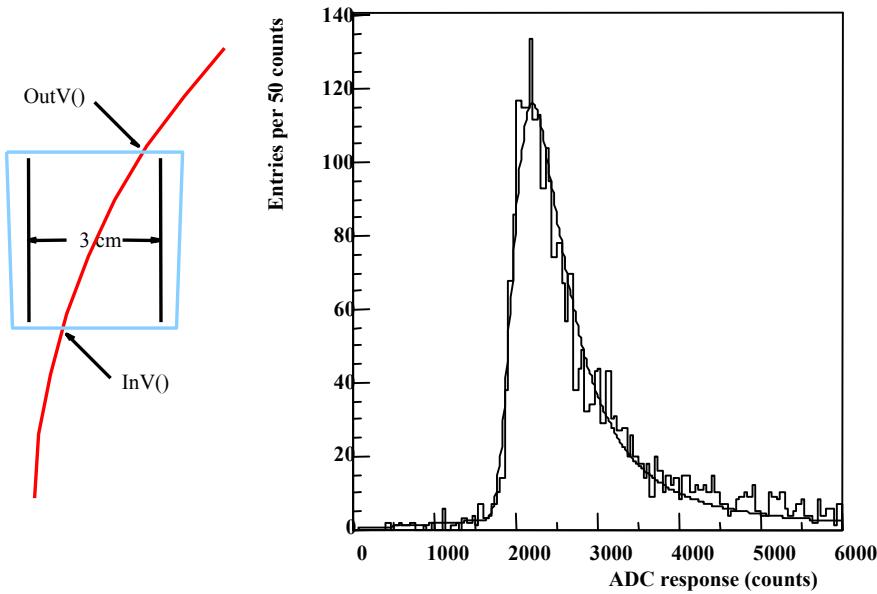
Hardware Calibration: TAC

- Time to Amplitude Converter routinely calibrated with DDG \Rightarrow picoseconds perTDC count ratio.
- Good stability over more than half a year.
- Still this difference is subtracted by the calibration



Data Calibration: Charge measurement

- Used for Time slewing correction and HIP trigger
- Z dependence : Exponential attenuation + border effects.
- Landau charge distribution after correcting for attenuation.



Data Calibration: Time measurement

For a track hitting a bar at z and being Q the charge read by the channel i .

$$t_i = Tof + t_i^0 + t^0 + (L/2 \pm z)/v + F_i(Q)$$

Where :

t_i is the measured raw time in channel i

Tof is the time from collision point to scintillator

t_i^0 channel dependent time offset

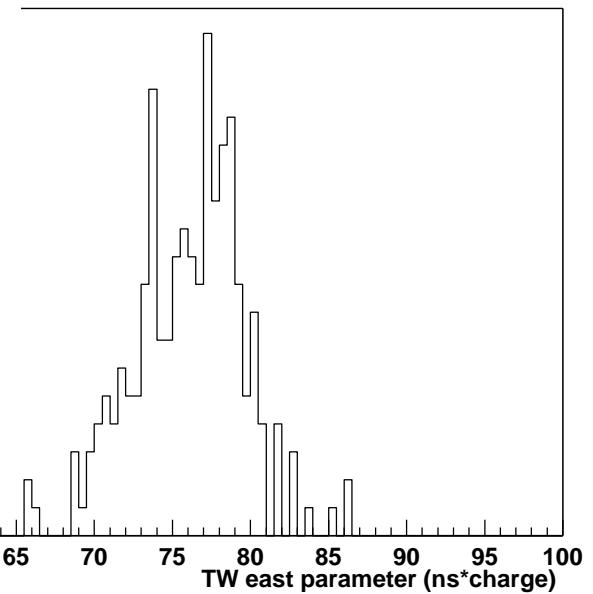
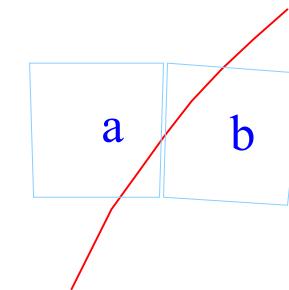
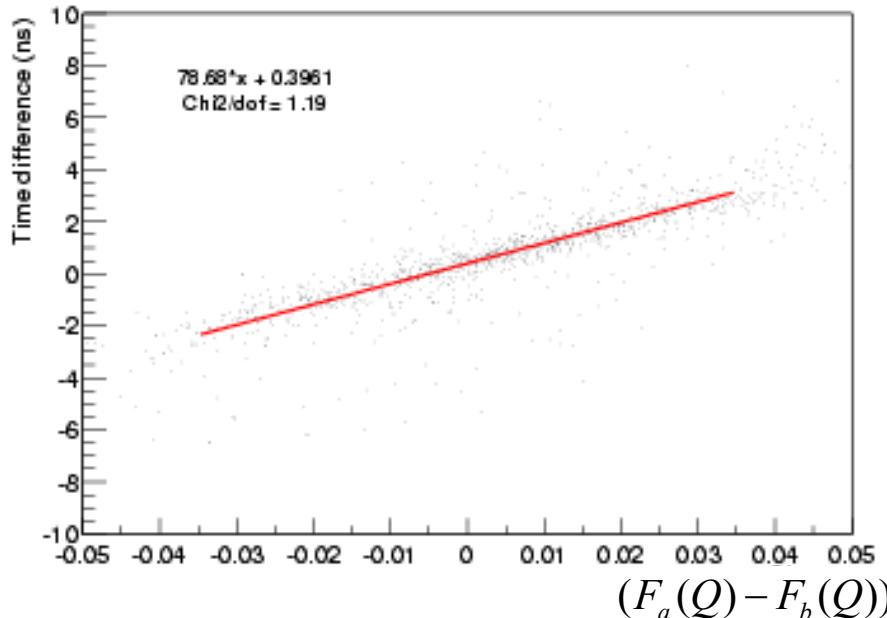
- cables, electronics delays -

v speed - of - light in scintillator

$F(Q,z)$ Time slewing dependence on Q

Data Calibration: Time Slewing correction

- A few nanosecond effect over all pulse amplitude range.
- Tracks traversing more than one adjacent bar $t_a \approx t_b$



- T-W parameterization:

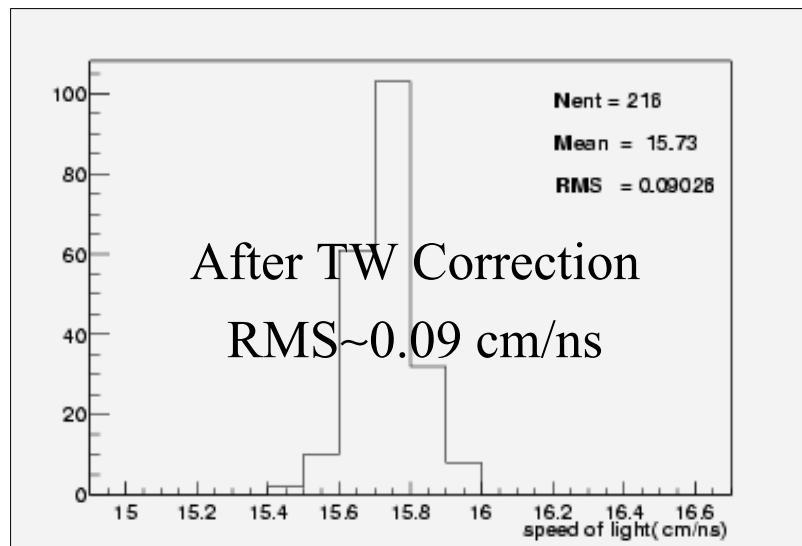
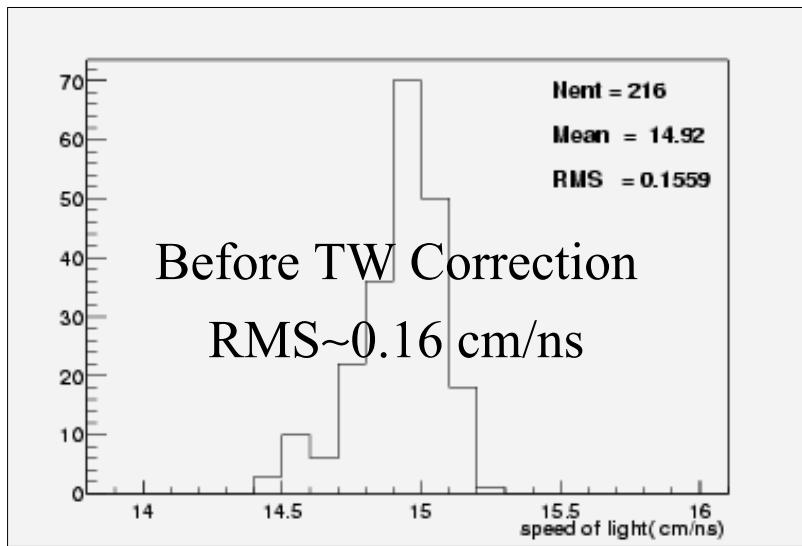
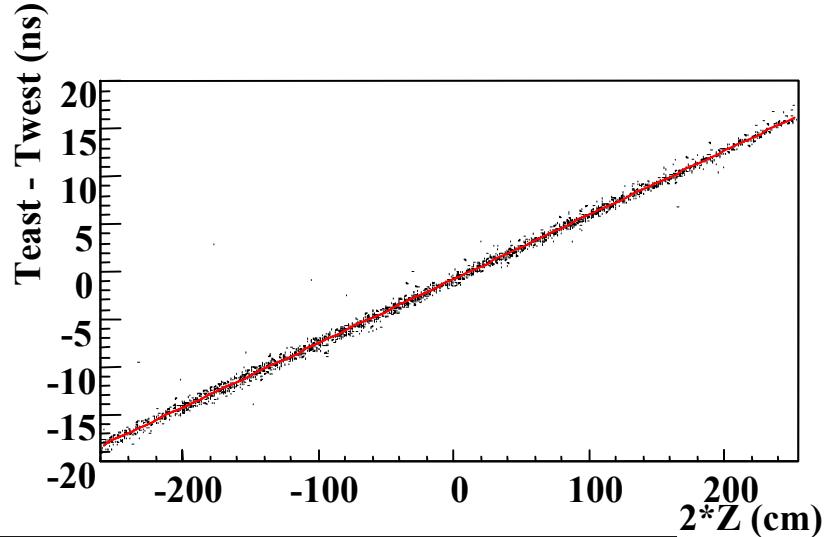
$$F(Q) = -\alpha \sqrt{Q/Q_0}$$

Data Calibration: Time Difference vs. Z

- Time difference between $z > 0$ and $z < 0$ pmts (east-west)

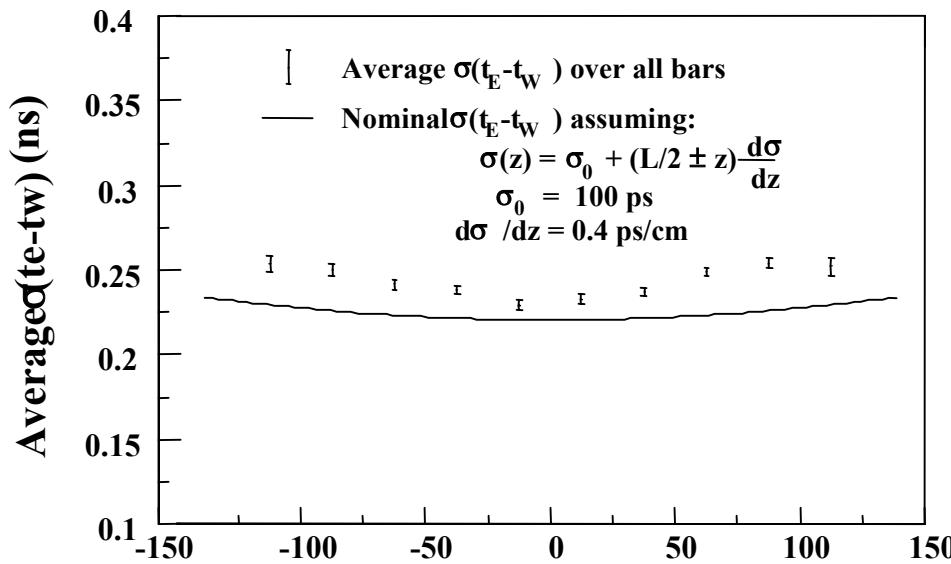
$$t_e - t_w = t_e^0 - t_w^0 - (F_e(Q) - F_w(Q)) + 2z / v$$

- The time walk dependence is absorbed in the fit.

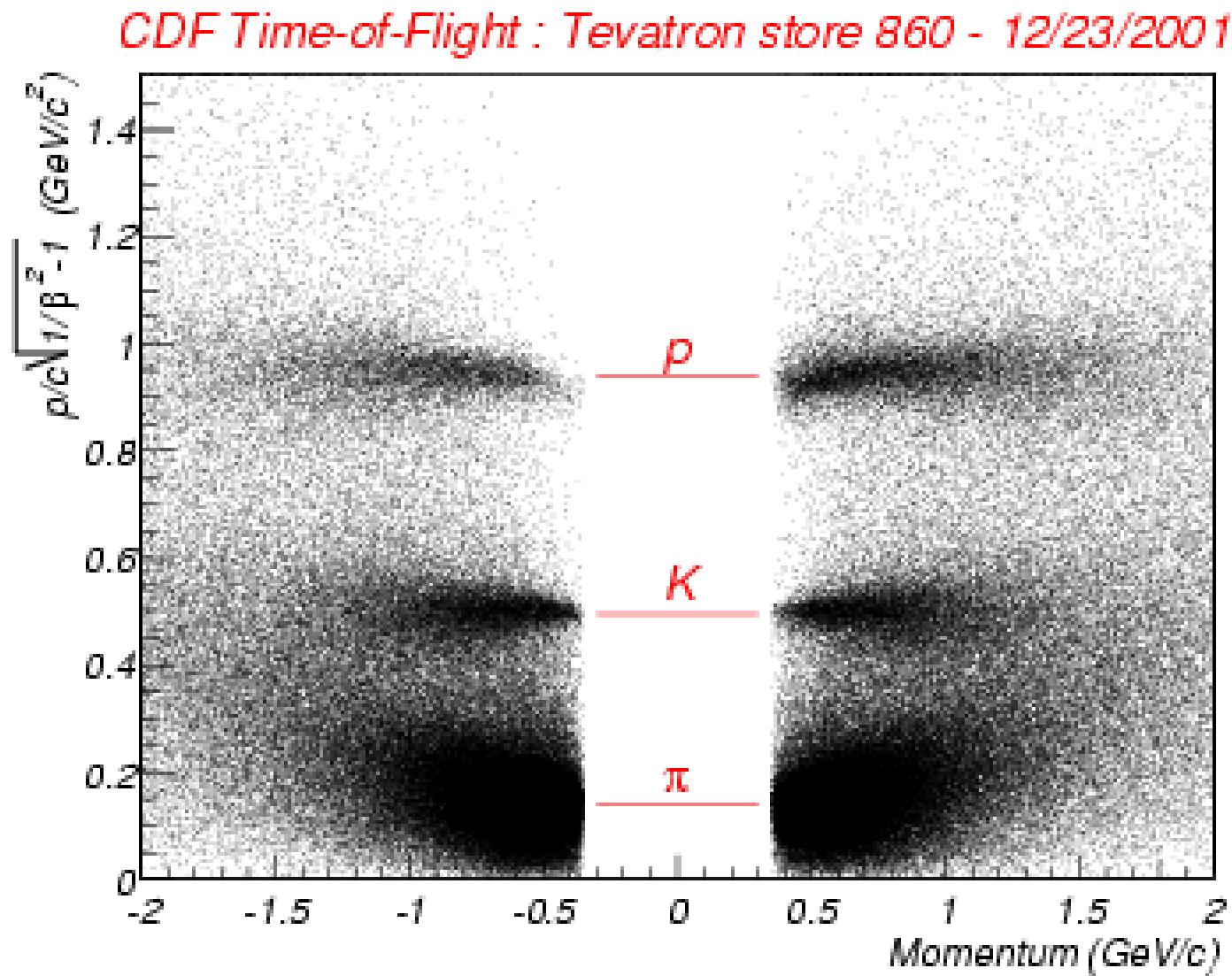


Time Difference resolution

- Target performance: 100ps resolution over length bar using both PMTS
- Comparison between the time difference for east and west pmt with 100ps resolution Montecarlo ($\sigma_{\Delta t} \approx 2 \sigma_{TOF}$)
- From this “systematic-free” time difference resolution preliminary $\sigma_{TOF} \approx 125$ ps
- Working on the improvement



Mass separation vs. momentum



Summary and Conclusions

- The new TOF detector for CDFII has been described.
- Fully installed since Aug. 2001
- Initial performance indicators shown:
 - 100ps resolution seems feasible.
 - Hardware working well.
 - Data quality is good.
- Hardware calibration completed
- Ongoing work on data calibrations
- Expect particle ID for physics soon.

The Detector: PMT-bar coupling



- Optical coupling between scintillator bar and pmt done with:
 - Parabolic light concentrator (Winston Cone)
 - Bicron silicone pad ("Cookie"), to match the index of refraction between the bar and the winston cone.
Avoiding air gap and suppressing light reflections.
 - The pmt is mechanically held against the bar with a spring

Data Calibration: Bars azimuthally survey

- Use reconstructed tracks with drift chamber to survey the TOF.
- Found systematics of several mm with respect to the photogrammetric survey.

